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OBSERVATIONS ON THE STORAGE OF GRASS SILAGE

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by

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U. S. Department of Agriculture

Grass silage has been defined as silage made from any uncured hay or forage crop. Its use has become widespread during the past few years and, as a result, some problems have arisen that require engineering research for solution.

Silo deterioration and failures brought demands from farmers for assistance, and to meet this demand an investigation was instigated at the New Jersey Agricultural Experiment Station in 1937 with the cooperation of the Bureau of Agricultural Chemistry and Engineering, United States Department of Agriculture, to measure the pressures exerted on silo walls by grass silage. The project has now been expanded to include investigations on juice control, protection of silos from the action of silage acids, and harvesting methods and machinery. This expansion has been materially assisted by a research grant made jointly by the American Steel and Wire Company with the Carnegie-Illinois Steel Company, the National Association of Silo Manufacturers and the Portland Cement Association.

The term "silo failure" as used in the preceding paragraph has added significance. In the past when a silo failed it burst. Now that leakage is more prevalent, farmers have become juice conscious and are demanding silos that will not leak. The term "failure" then has gained broader meaning and a silo may be said to fail not only if it bursts but also if it leaks, deteriorates or disintegrates. While this definition may not be universally accepted, it does indicate a condition that must be met in silo design.

#### Juice Control

The juice in grass silage presents a sort of "poly-phase" problem. In high-moisture silage it may, and frequently does, leak or drain from the silo causing offensive odors, damage to any concrete or metal reinforcing over which it flows, and some loss of nutrients. Its control may be approached in several ways. One is to wilt the green crop in the field until its moisture content is lowered to between 65 and 70 per cent. Reports from farmers indicate some success with this method but considerable experience is required to determine when wilting has progressed to the proper stage. Wilting is also dependent on favorable weather, and the introduction of a fair weather factor in the production of grass silage is not desirable.

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(1) Presented at the Twenty-Eighth Annual Convention, National Association of Silo Manufacturers, Chicago, December 2, and the meeting of the American Society of Agricultural Engineers, Chicago, December 4, 1940.

(2) Assistant Agricultural Engineer, New Jersey Agricultural Experiment Station and Assistant Agricultural Engineer, Bureau of Agricultural Chemistry and Engineering, U. S. Department of Agriculture, respectively.



A second method is to add to the chopped material some dehydrated preservative such as oat hulls or citrus pulp fortified with molasses to absorb the free moisture. It will be noted in Table I that two silos, L5, 1940 and B1, 1938, were filled using this type of preservative and that there was no leakage even with the high moisture green material. Corn meal and ground ear corn are now being tried as moisture absorbing preservatives. A third method reported as practiced by middle western farmers is to use a longer cut on the chopper when ensiling material of high moisture content. Along this same line, the Papco Machine Company is advising its customers to vary the length of cut with the condition of the green material, suggesting a  $1/4$  inch for low moisture,  $1/2$  inch for average, and 1 inch for high moisture. This sounds promising and should be investigated under controlled conditions.

In some instances it may be desirable to rid a silo of free juice. Therefore, considerable thought is being given to drainage systems for silos and to preventing seepage at points other than drains. In 1939 three drains were placed in the walls of two 18 foot silos, B4 and B5, Table I. One of the three drains was a 1.5 inch pipe placed opposite the doorway and flush with the inside wall and foundation. The other two were 2.5 inch pipes placed about 6 inches above the foundation and opposite each other in the wall midway between the first drain and the doorway. One silo was filled with 188 tons of phosphoric acid grass silage and the other was filled with 198 tons of molasses grass silage. The average moisture content of the ensiled material in each case was 68 per cent. The drainage loss from the acid silage was 975 gallons of juice, representing 2.24 per cent by weight of the ensiled material. The drainage from the molasses silage was 3,990 gallons, representing a loss of 9 per cent. A point of particular interest is that all of the juice lost from the silos came through the drains. For 1940, using the same two silos, one was filled with 333 tons of phosphoric acid grass silage and the other with 318 tons of molasses grass silage, moisture content in each case being approximately 77 per cent. The leakage loss from the acid silage amounted to almost 16 per cent, while the loss from the molasses silage was about 18 per cent of the total ensiled weight. The drains functioned but carried only part of the leakage. Most of the loss occurred around the doorway, not unexpected because of the pressure panel construction. Some leakage through the stave joints occurred up to a height of 18 feet in each silo. The joint leakage in 1940 was associated with the higher pressures which amounted to almost twice the values measured in 1939. A rock fill about 3 feet in diameter with drain in the bottom was used in silo B6 in 1940. Filled with 97 tons of phosphoric acid grass silage at 70 per cent moisture, the seepage amounted to approximately one per cent, all coming through the drain. Other types of floor drains and vertical wall drains are to be tried.

The hoops on silos B5 and B8 were tightened to produce a stress in the steel of approximately 18,000 pounds per square inch so that the staves might be held together with some force even after the silos were filled. Preliminary observations indicate that prestressed hoops will limit the leakage through the vertical joints of concrete stave silos but cannot be expected to entirely control the leakage problem because of the irregular joint surface found on concrete staves. Horizontal joint leakage was more noticeable when the vertical joint leakage was reduced. In prestressing hoops, considerable difficulty was encountered in holding the stress on intermediate hoops that do not cross the door opening but are held by spreaders. Faulty design, particularly



on spreaders carrying more than one hoop, has been evident. One common fault has been the reduction of effective area of the spreader strap by rivet holes. Improvements that have been noted include the use of continuous heavy angles along the door opening, instead of spreaders, to which the hoops are attached. The angles are held by heavy rods across the door opening at sufficiently wide intervals so as not to interfere with the removal of silage. Welding to strengthen riveted members is also in evidence.

Plastic calking was placed in most of the horizontal joints of three courses of staves in silo B8 to observe its effectiveness as a joint seal. From this one test the value of the calking may be questioned, as there was a small amount of joint leakage in the bottom two stave courses with little to choose between calked and uncalked joints. In any case, its value must be very pronounced to offset the cost of materials and application.

#### Coatings

To effectively seal the interior and protect the concrete stave silos, some 24 different coatings have been applied. The materials include asphalts, coal tars, oils, paraffin wax, rubber paints, synthetic resins, special plasters, varnish, and waterproofing. Results to date have not been too promising. It has been difficult to get a lasting bond between the coating and the concrete. Tests of coatings are also underway in tile block silos where difficulty has been experienced in maintaining the mortar joint and in steel silos. More durable mortar must be found for block silos as the types now used disintegrate rapidly and leave the reinforcing exposed to the action of silage acids. This will reduce the area of steel and weaken the silo if allowed to continue.

Considerable work has been done in the past on the strength and durability of concrete and concrete staves and protective coatings for concrete. Probably the most extensive work along this line has been a cooperative project between the United States Department of Agriculture and the Agricultural Experiment Station of the University of Minnesota under the direction of Mr. D. G. Miller. The results of some of these tests pertaining in particular to concrete stave silos were published as Paper No. 1713, Scientific Journal Series of the University of Minnesota. While many means of protecting concrete and mortar from acids have been studied, as yet no substitute for a rich well-proportioned mix has been found.

The Portland Cement Association has cooperated with different state agricultural experiment stations in making studies of various protective coatings for masonry silos. As a result of their work they recommend several coatings that may be effective for from 1 to 5 years. The American Concrete Institute through its committees is also investigating means of prolonging the useful life of silos.

#### Pressures

The equipment being used to measure pressures in silage was developed by the Bureau of Agricultural Chemistry and Engineering, U. S. Department of Agriculture, and is described in the Journal of the American Society of Agricultural Engineers for June 1939. Silago pressures have been measured

unison and collective idea had been one of art and poetry's most  
powerful weapons to move people to collective self-help and find  
ways around the new oil shock/oil boom road ahead. However,  
one trend out of the oil boom was to develop a more rural and rural culture  
than the urban road out across the vast oil fields and cities and abundant  
possibilities to develop oil-rich extraction or live as an oilfield wife without  
having to leave at all stages having no adequate or sufficient

jobs. The result, however, led to deep oil fields and suffice cities.  
Also fuel, as an economic base, led people to sequences of oil wells to sequence  
and work as plantations of open fields led to oil as fast one side over  
of which dry season winds and worked out of control just to turn these  
oil fields over and pass them to another railroad and Pacific railroad roads  
and pipelines for extraction to live off their oil fields.

### Conclusion

While many extraction and trapping have withdrawn out from Mississippi of  
indigenous cultural activities and believe good and badness intertwined ones  
between nature, culture, spirituality and art, also, yet this  
not used too much which of indigenous communities has become, especially  
native, local life of environment and extraction to also, persistence will also  
be true when oil extraction and exploitation of resources and oil industry  
comes out as well as the rest of the nation's economy will suffer from  
native oil to become industrial and rural has suffered especially because now  
oil cities and towns have come to mind and easier life will, also, realize to  
influence of people

but individuals who do have oil as such one and have established  
communities with extraction activities have certain extraction to utilized  
activities as well as oil extraction activities from oil extraction  
activities, and have developed the traditional native belief and created to bring  
the extraction activities "concerned" to extraction will be held the traditional and  
cultural oil extraction a sense again to come to closer off, will be oil  
extraction, oil extraction, oil extraction, and oil extraction, extraction of  
these activities to come again oil extraction to utilize the oil in various  
ways to get extraction as they as follows it is not often seen when part of the  
people need an oil extraction.

That there will be the better road and traditional jungle forest and  
original culture to culture value of lands that are found through  
the oil extraction, so they should be closer to the oil extraction and  
the original culture will always be oil extraction and extraction  
and extraction to come into the traditional jungle forest extraction  
which is still left up all

### Conclusion

Successful moves the oil extraction, indeed, of those raised in groups off  
the traditional oil extraction but yet also for extraction to understand  
the oil extraction as to how to extract oil as the types of the extraction  
beginning and end community oil life, which will not expand extraction

in 7 silos at the New Jersey Station and one at the Beltsville Research Center of the Department of Agriculture, aggregating 12 tests on grass silage and 7 on corn silage. Readings were taken as each 2 or 2-1/2 foot layer of silage was placed in the silos so that the number of individual panel readings taken during the filling of the various silos ranged from 75 to 150 with additional readings being taken each morning and evening during filling and each day during the settling period. The panels averaged about 4 square feet in area. Results are quite variable as may be seen from Figure 1, which summarizes the lateral pressures. Maximum values for grass silage vary from 159 pounds per square foot in a 12-foot diameter silo with 64 per cent moisture silage at a 25 foot head, to 1189 pounds per square foot in an 18-foot silo, with 77 per cent moisture silage at a 40-foot head. This is a range of from approximately one-half to two and one-half times the pressures commonly considered in silo design, which is 12 pounds per square foot per foot of depth.

Factors that affect the amount of lateral pressure on silo walls, in addition to depth, are the moisture content of the silage and its distribution, the preservative used, the diameter of the silo, the fineness of cut, speed of filling and type of material ensiled. The 12 tests on silo pressures with grass silage that have been run to date show the effect of moisture content and the type of preservative. Figures 2 and 3 show how the pressures in 12 and 14-foot diameter silos increase as the moisture content increases. There are some differences in the type of preservative used in these silos, but since the moisture content varies in each case and there are some differences in the materials ensiled with different preservatives no direct comparisons on the effect of preservatives can be made for these silos. Figure 4 demonstrates the effect of both moisture content and preservative in 18-foot-diameter silos. Curves 2 and 5 show the increase in pressures with molasses silage over the pressures with acid silage given in curves 1 and 4. Since the silos represented by curves 1 and 2, also those represented by curves 4 and 5, were filled simultaneously, the effects of diameter, material and moisture content were eliminated and all the differences can be attributed to the preservative. Similarly the increase in pressure found when comparing curve 1 with 4 and curve 2 with 3 and 5 can be attributed to moisture content. The fact that the curve 2 crosses curve 3 between the 25 and 30 foot levels can be ascribed to the difference in the material ensiled in the two silos and the fact that the silo represented by curve 2 had the bulk of the low moisture material in the bottom part and comparatively high moisture silage on top, while the silo represented by curve 3 was filled with silage of a uniform moisture content throughout.

#### Capacities

Silo capacity as well as pressure is influenced by moisture, silo size, and fineness of cut. It has been observed that with average moisture grass, taken as 65 to 72 per cent, the smaller or average sizes of silos will hold about the same tonnage of grass as corn. Table I. Those holding a greater total tonnage of grass are about balanced by those holding less. As the moisture content is increased, the total tonnage is increased and vice versa. Silos filled with high moisture grass have held up to 50 per cent greater tonnage than would be expected with <sup>normal</sup> corn silage. In each case, however, the variation of the dry matter capacity of the silo is slight.



## Summary

Foundation drains show promise of satisfactory operation, particularly when pressures are not excessive.

Vertical joint leakage from concrete stave silos may be controlled to some extent by prestressing the hoops. Joints must be redesigned or provided with seals before general satisfaction can be expected.

Results of the New Jersey tests on coatings for concrete are not at all promising. However, other observations seem to indicate that varnishes and synthetic resin with wood oil vehicles, asphalts, coal tars, and Portland cement washes show promise of giving some satisfaction. In choosing an asphalt or coal tar preparation, care should be taken to select one that has a high melting point in order to minimize sticking of the silage. Some suggestions regarding silo coating are given in Bulletin CP 14 of the Portland Cement Association.

Silos should be adequately reinforced. Tables 8 and 9 in U.S.D.A. Farmers' Bulletin 1820, give reinforcing schedules that are adequate.

Silos with exposed reinforcing are likely to be more satisfactory for storing high moisture silage since such reinforcing can be prestressed, or drawn sufficiently tight when the silo is erected to overcome the effect of the silage pressures, thereby lessening the tendency for cracks to open in the walls. It can also be inspected at will and repairs or replacements easily made when necessary.

Under usual farm conditions the average size silos will hold about the same tonnage of grass as corn.

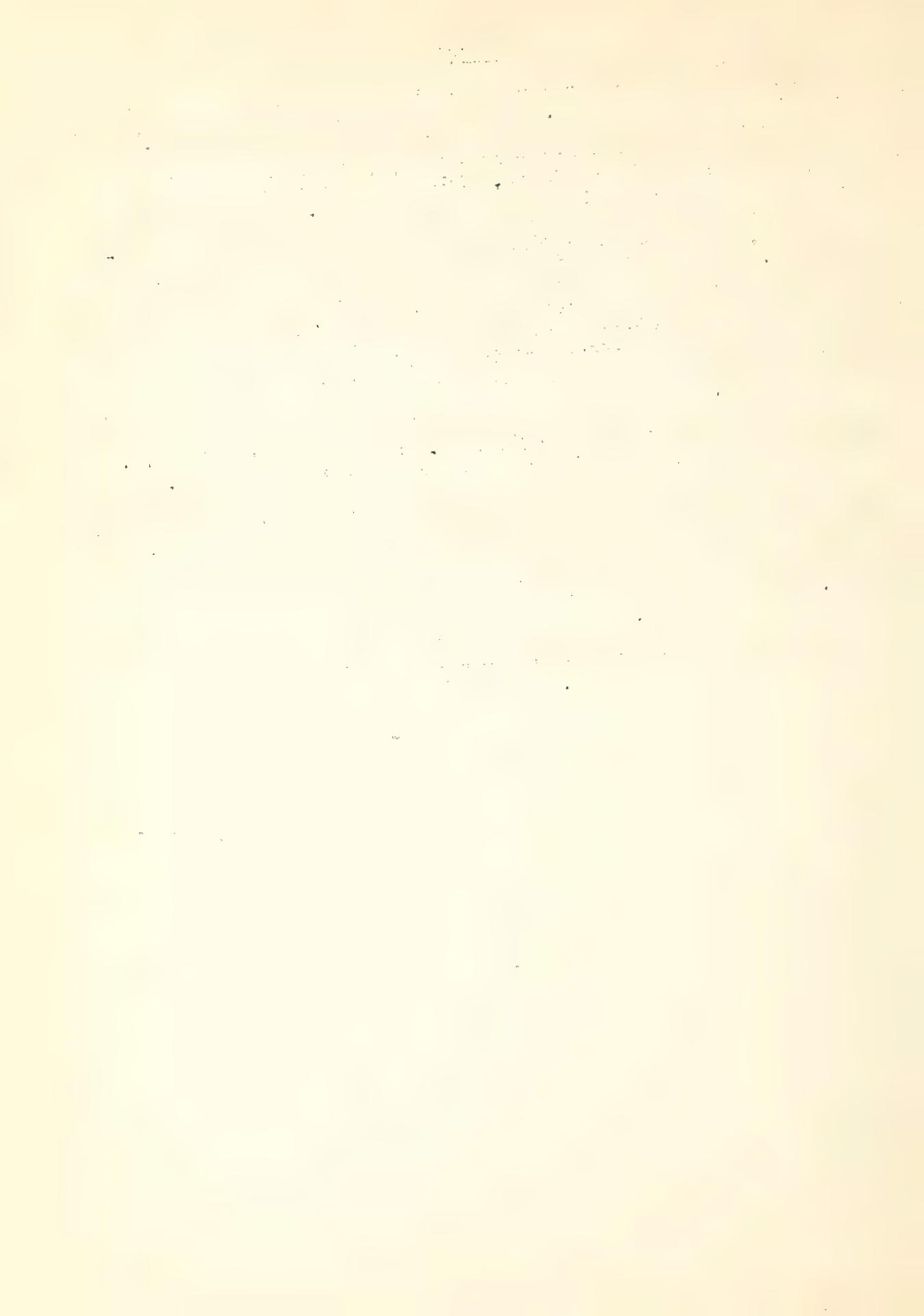


Table I

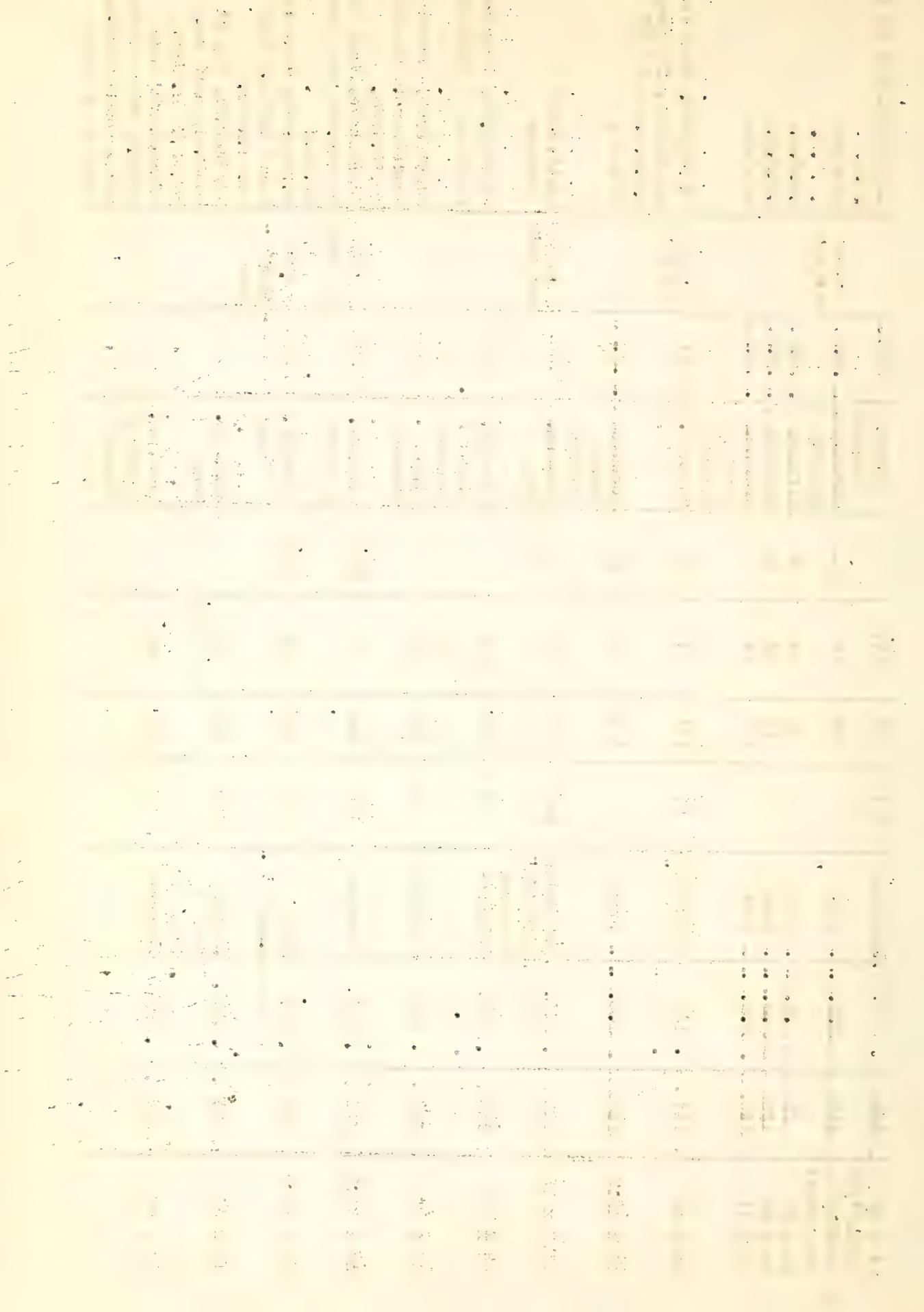
## SILO INVESTIGATIONS - GRASS SILAGE DATA (1)

N. J. Agricultural Experiment Station and U. S. Department of Agriculture Cooperating

(2)	(3)	Normal Capacity tons of green material ensiled, corn silage	Preservative added	Total tonnage	Moisture Content (in silo) %	Settled Depth feet	Lateral pressure lbs. per sq. ft.	Maximum pressure lbs. per sq. ft.	(4)	(5)	(6)	(7)
10x25	36	36	none	36	72				U. S. D. A.			
10x25	36	32	none	32	68				U. S. D. A.			
11.6x30.	64	60	Molasses	100	63	low			NJ, B9, 1938. Mature crop, considerable spoilage in top 3rd. No leakage.			
11.6x28.5	61	77	Molasses	77	80	71			NJ, B9, 1939. Good silage, some mouldy spots near top. No leakage.			
12x30	68	43	Molasses	300	49	low			NJ, LA, 1938. Spoilage spots throughout silage, No leakage.			
12x30	68	61	Phos. Acid	16	62	av.			NJ, LA, 1939. Excellent silage. No leakage.			
12x28	61	48	Molasses & "Silo Germ"	43	49	64			NJ, B6, 1939. Top spoilage.			
12x41	104	150	Molasses	125	159	78			24 t. moist. oats on top of 24 t. low moist. alfalfa.			
12x41	104	95	Phos. Acid	24 & 24 water	97	70			NJ, B6, 1940. No leakage, approx. 1% Seepage from floor drain.			
14x33	105	82	Phos. Acid	16	83	av.			NJ, L2, 1938. Good silage, except in pit which needed drainage. No leakage.			
inc. 6' pit									Mixed Grasses			







18 x 40	224	200	Molasses	100	210	low		Mixed Grasses	84
18 x 40	224	330	Phos. Acid	20	333	77	35	Alfalfa	77
18 x 41	231	308	Molasses	66	318	77	35	Alfalfa	73
18 x 42	237	332	Molasses	100	349	high		Alfalfa & Clover Oats and Peas	80
18 x 42.5	240	263	Molasses	40	268	72	37		75
									801, 42.5% head fill.

#### Notes

(1) Messrs. Claude Eby and W. H. Tamm, N. J. Agr. Exp. Sta., assisted in preparing data for table.  
 (2) Refers to silo diameter and depth of silage immediately after filling.  
 (3) From U. S. D. A. Farmers' Bulletin 1820.  
 (4) Low moisture content assumed to be below 65%, average 65-72%, high over 72%.  
 (5) 30 days after filling.  
 (6) For approximate values, low moisture taken as 60%, average as 68%, high as 77%.  
 (7) N. J. cutters set for 1/2" cut except as noted.  
 All N. J. silos sealed with mulch paper covered with at least a ton of chopped grass.  
 Spoilage refers to silage unsuitable for feed below seal.

#### Silo Types

- N. J. B1 to B8 incl. - concrete stave.
- N. J. B9, L5 - steel.
- N. J. L1, L2 - wood with 6" poured concrete pit.
- N. J. L4 - tile stave.

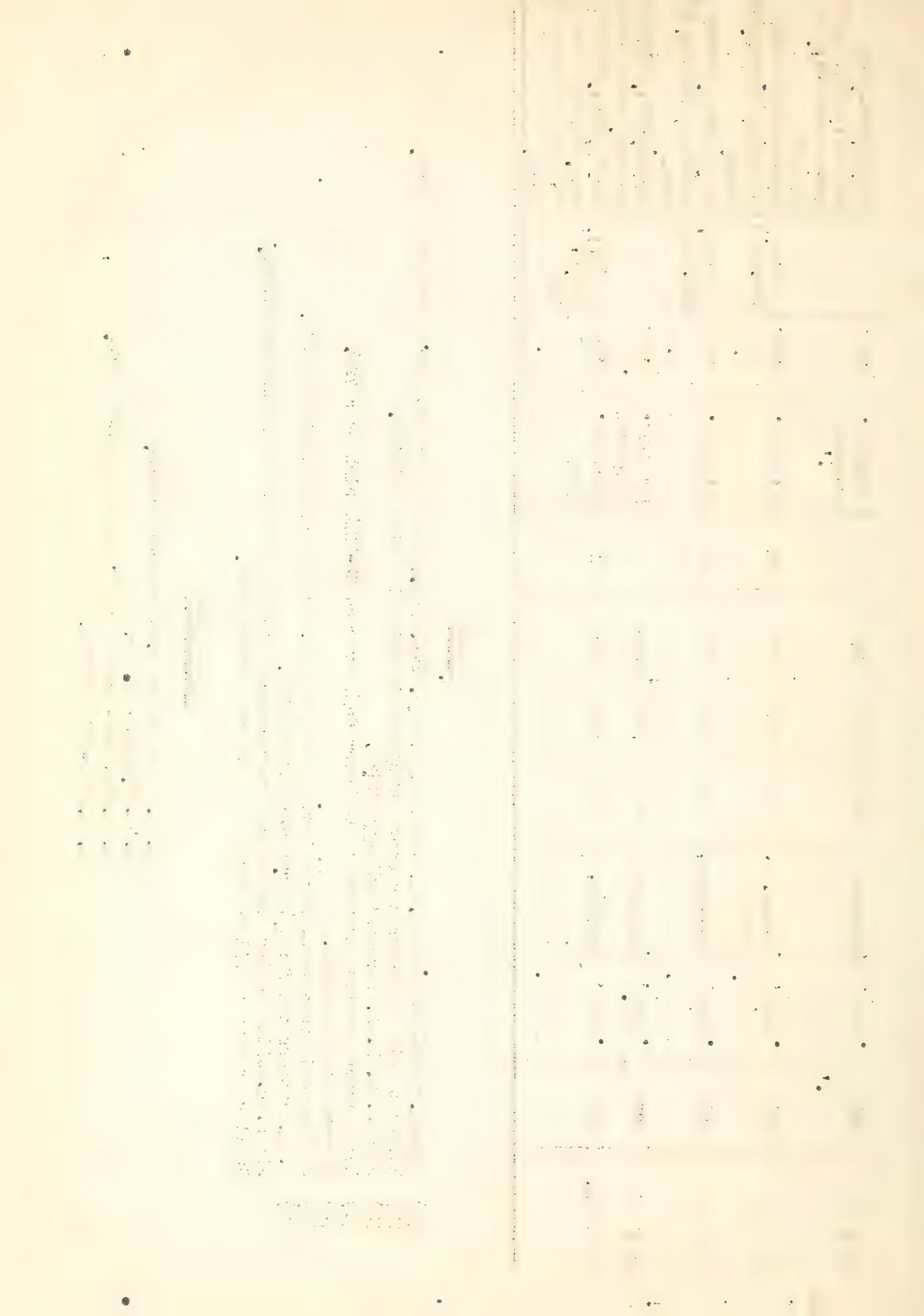
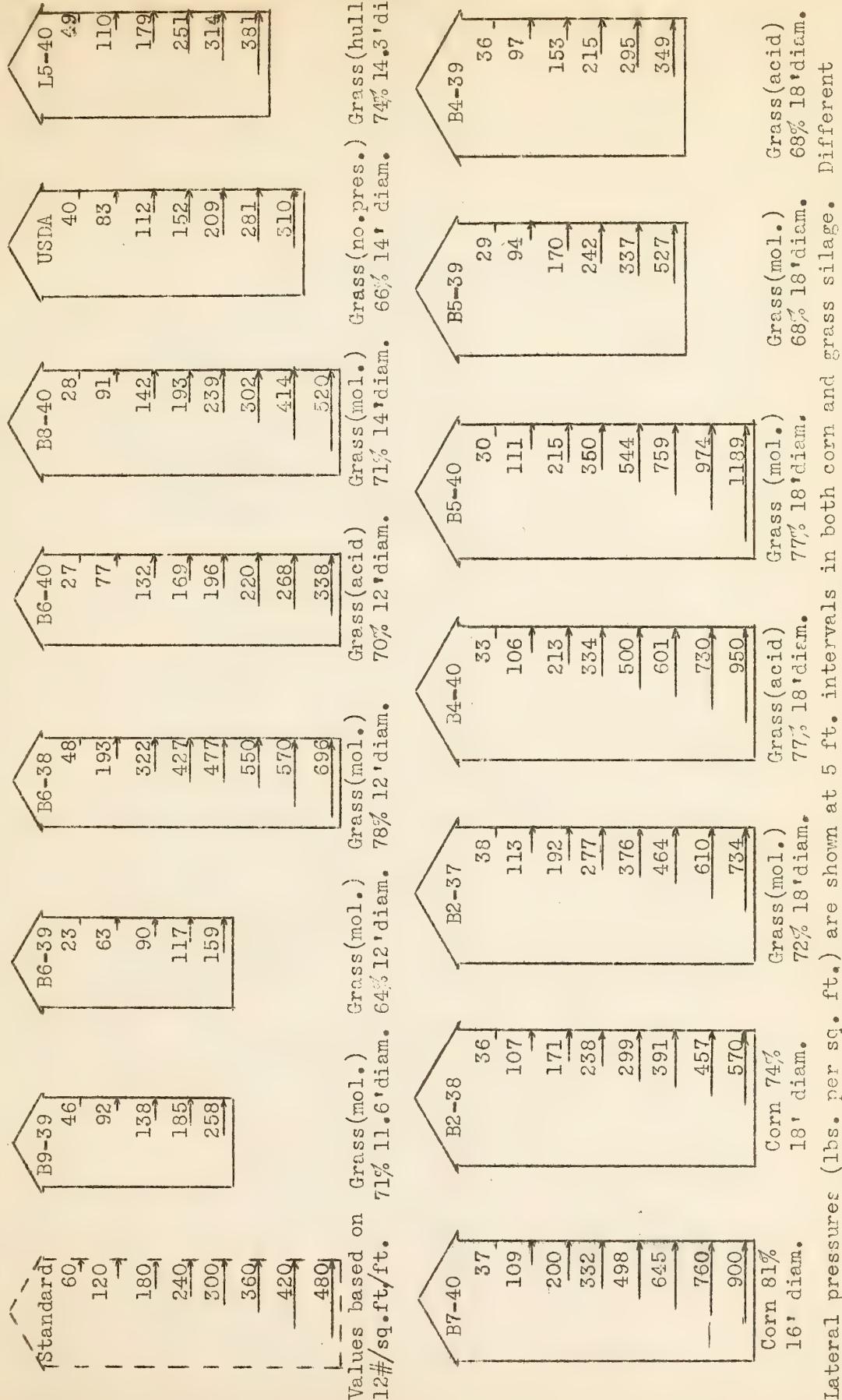


Figure 1.

Silo Pressure Investigations

New Jersey Agricultural Experiment Station and U. S. Department of Agriculture Cooperating



Lateral pressures (lbs. per sq. ft.) are shown at 5 ft. intervals in both corn and grass silage. Different preservatives, moisture contents and silo diameters are given. Supporting data may be found in Table 1, key numbers appearing under "Remarks". Pressures for "Standard" based on empirical value of 12 lbs./sq.ft./ft. of depth.

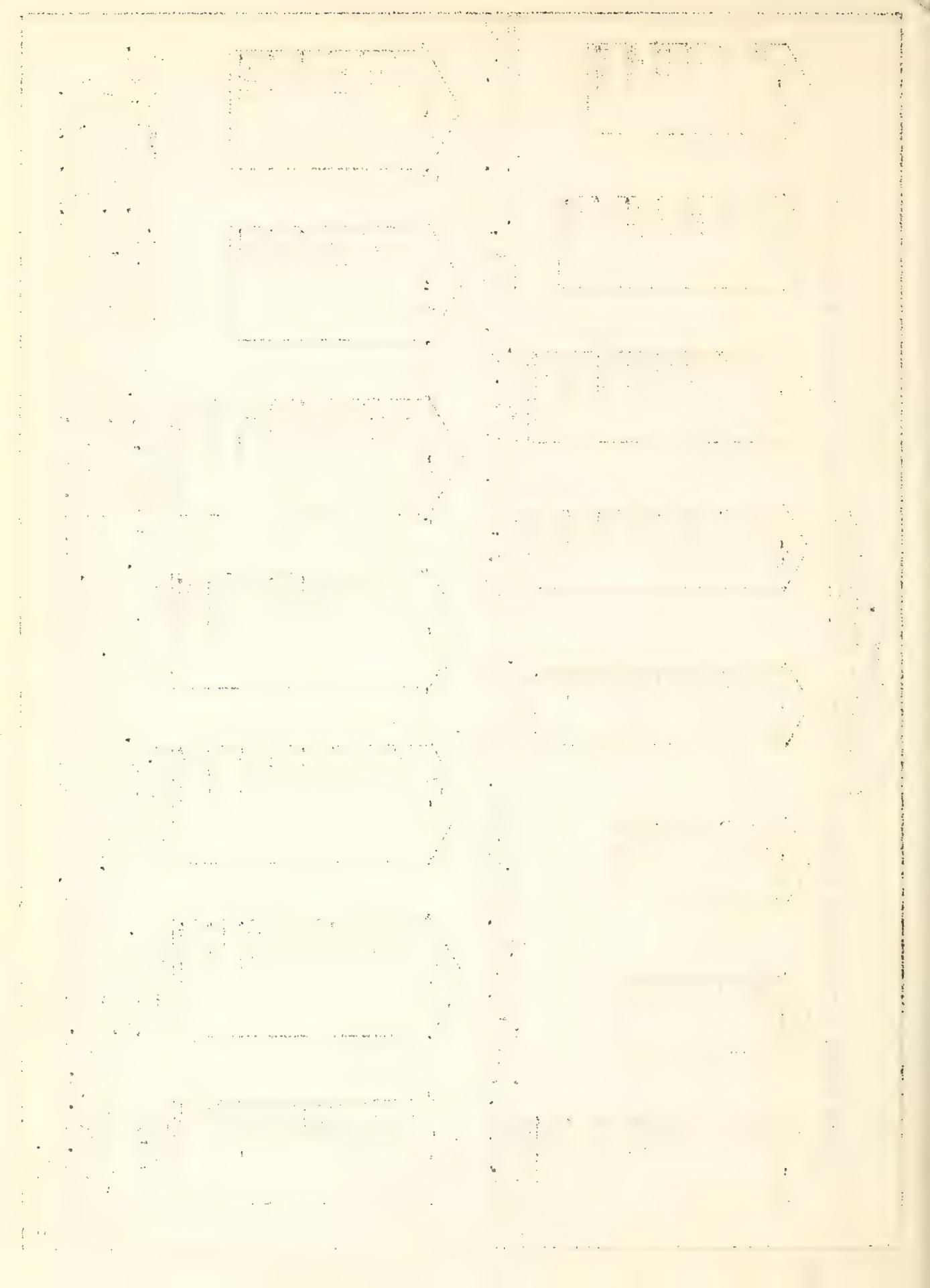


Figure 2.

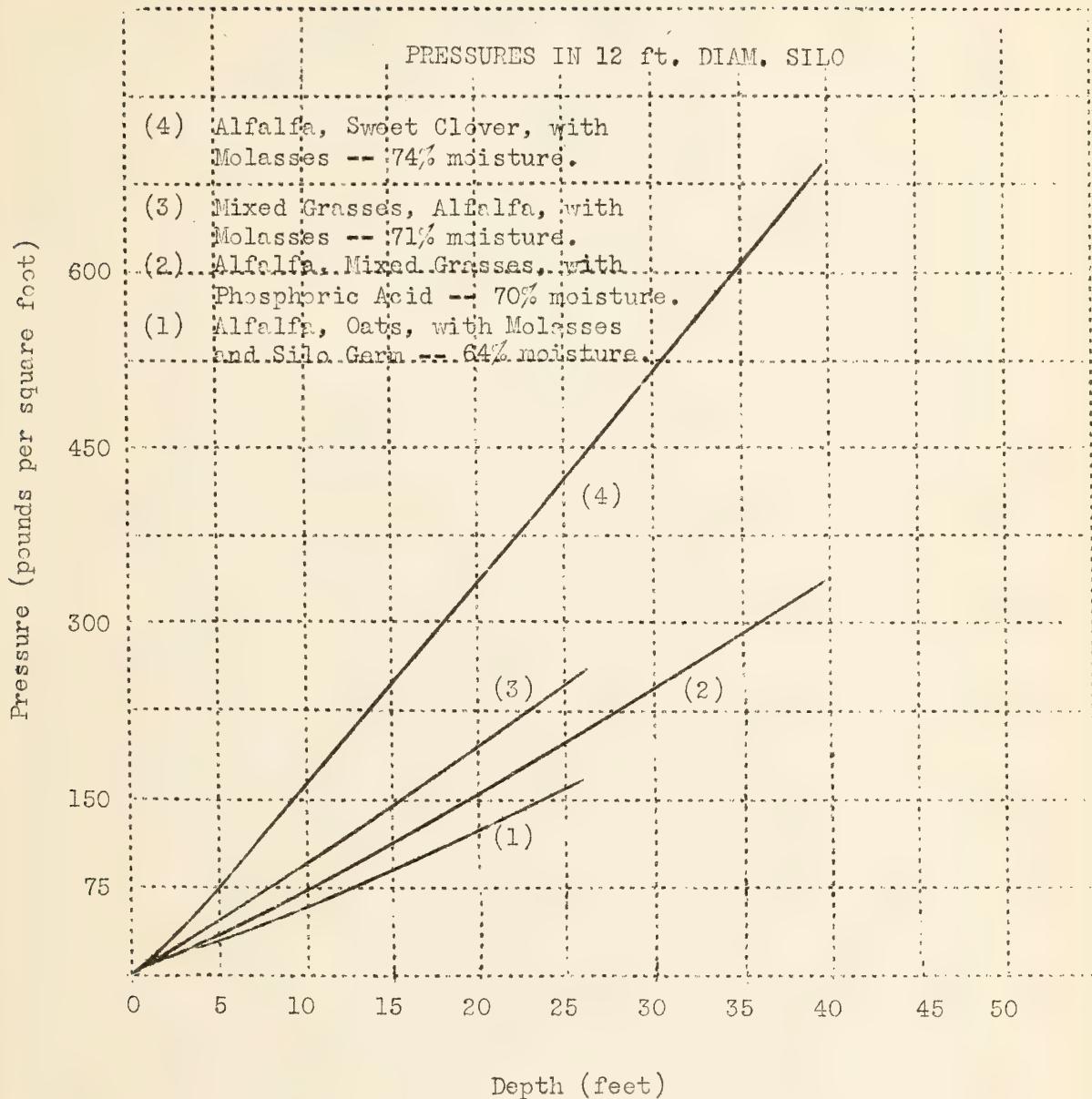




Figure 3.

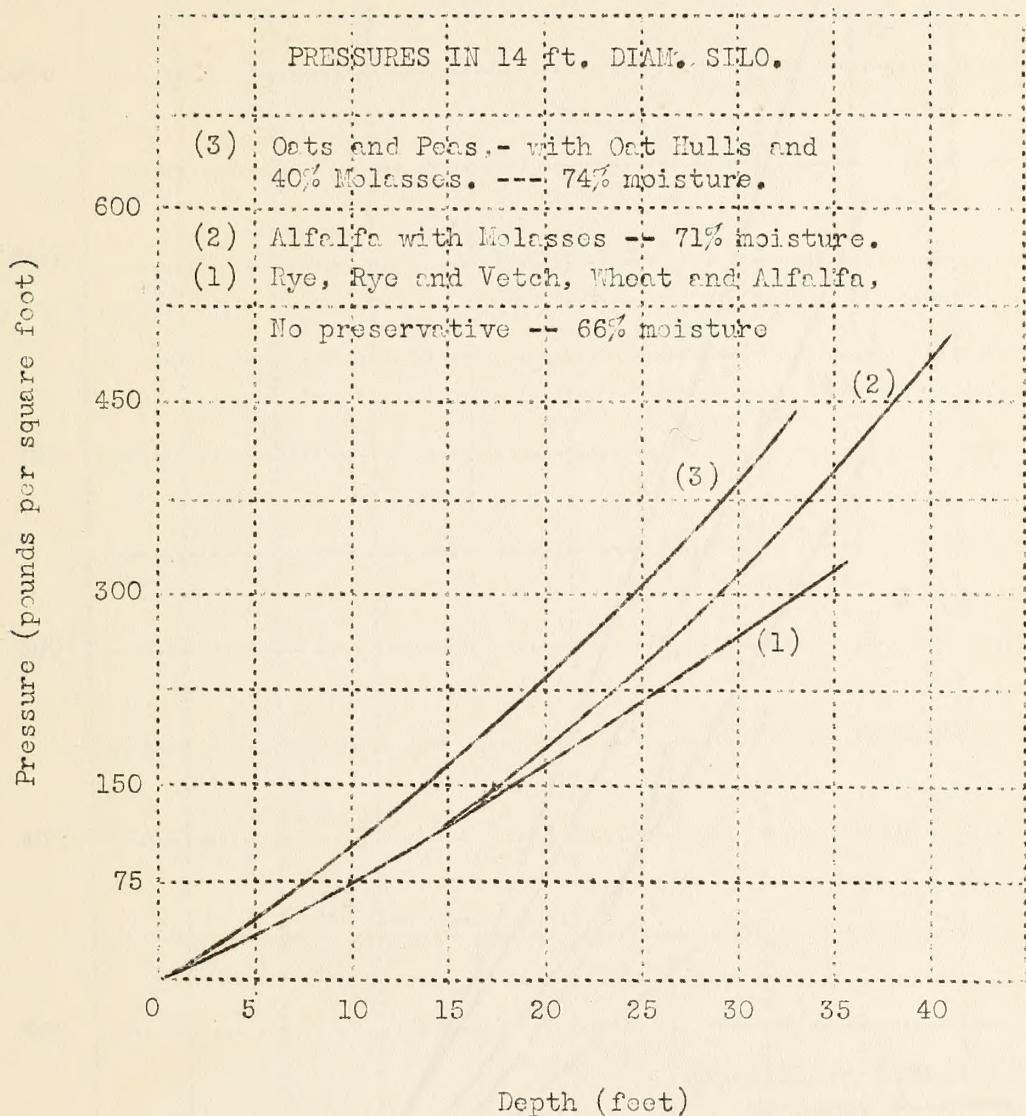




Figure 4.

